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(56) Documents Cited
GB 2286844 A GB 2266379 A GB 2081904 A
GB 2080537 A US 4196057 A

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(54) Abstract Title
Monitoring corrosion rate

(57) The rate of corrosion of an active metallic element 1 is measured using a reference element 2 and a reference resistor 9. The voltages across the elements 1,2,9 are measured by amplifiers 10,11,12 with a current source 8 both off and on, and the digitised values are used by a microprocessor 16 to calculate the resistance ratio of elements 1 and 2, corrected by a ratio indicative of the temperature of the reference element 2. The microprocessor uses a neural network algorithm. The corrected ratio is used to calculate the thickness of the active element 1 and deduce its corrosion rate.

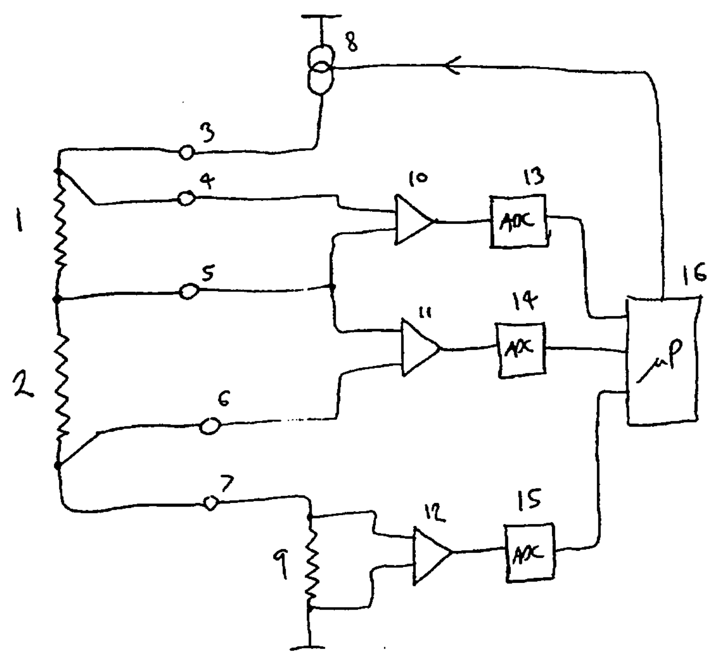

fig 1.

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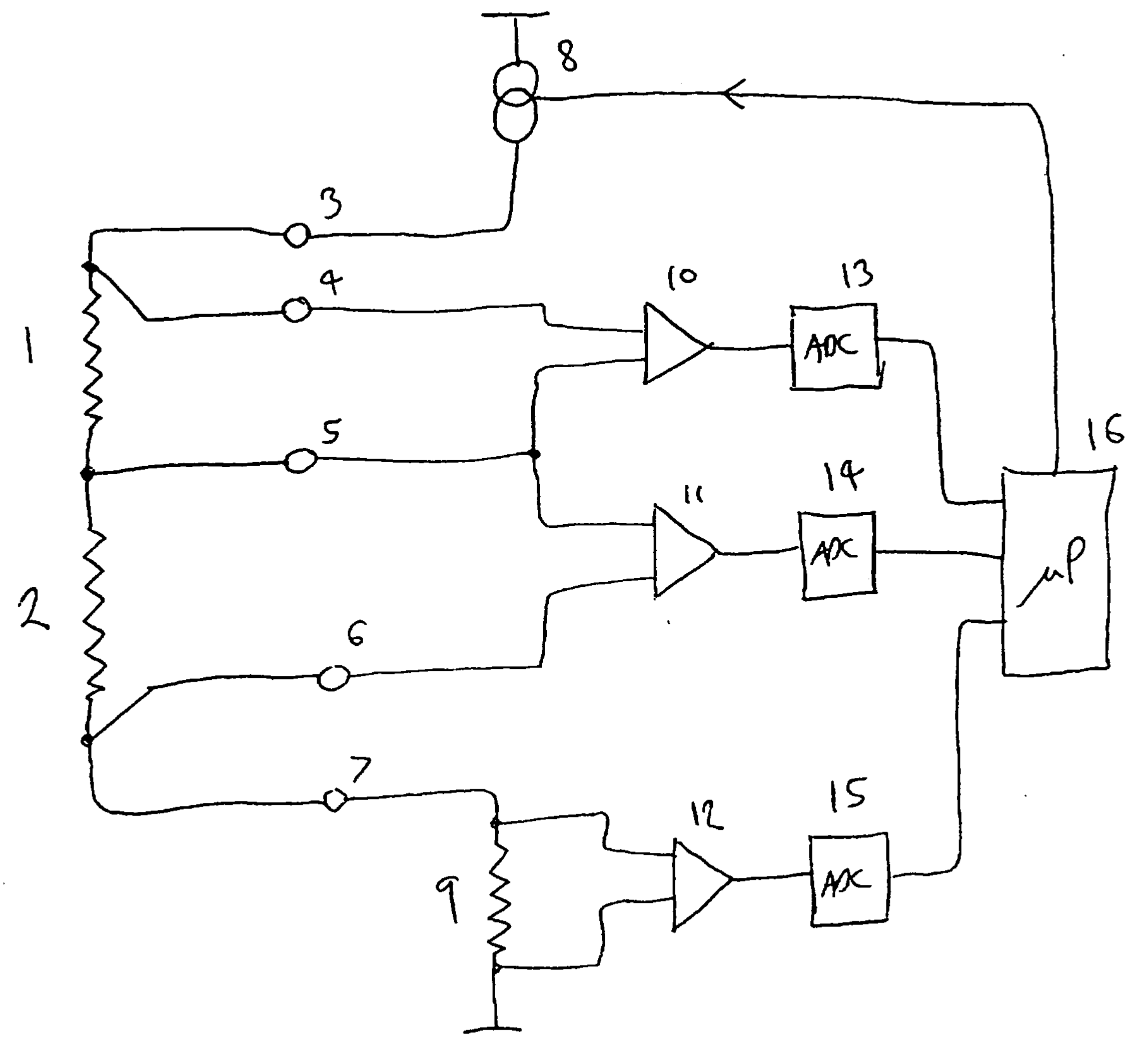

fig 1.

CORROSION MONITORING

This invention relates to corrosion monitoring. Corrosion causes enormous economic loss to industry. The ability to monitor the rate of corrosion allows corrective action to be taken. One method used to achieve this is the electrical resistance probe.

The electrical resistance probe (ER probe) consists of a thin element of metal, the resistance of which is measured by suitable instrumentation. As the element corrodes, the resistance increases due to the metal loss. The increase in resistance provides a measure of the corrosion rate.

The resistance, $\underline{r}$, of an element, of length L, of uniform cross sectional area, A, made of material of resistivity R, is given by:

$$r = R \times L / A$$

As the metal of the element corrodes, the cross sectional area, A, is reduced, hence increasing the measured resistance. As R and L and width are constant, measuring the resistance allows the calculation of the thickness of the probe to be calculated. As metal is lost, thickness is reduced, and the resistance increases.

The resistance changes are small, and the uncertainty of measurement is substantially affected by the temperature coefficient of resistivity.

To overcome this problem, a well-known method is to use a reference element, of a similar material, but protected from the corrosive fluids. A ratiometric measurement between the reference element and the active sensing element is then taken by the instrumentation, yielding a temperature-corrected value related to the corrosion rate.

Unfortunately, temperature transients can cause short-term differential temperatures between the active and reference elements, causing spurious corrosion rates to be computed from the basic ratiometric measurement. In addition, if the reference element and active element have slightly different metallurgical properties, there may be a difference in resistivity temperature coefficient between the two elements. This will cause an erroneous corrosion rate to be calculated at different temperatures, even when the temperature of the elements has fully stabilised.

According to the present invention there is provided a method of corrosion monitoring involving the use of a reference, or active, element wherein the absolute temperature of the element is sensed. This may be achieved either with a traditional RTD or thermocouple, or simply measuring the absolute resistance of the reference element.

The absolute temperature may then be used to apply a secondary correction to calculated active probe resistance, as computed from the basic ratiometric measurement.

Secondary correction = A. (T-T0) + B dT/dt

Where A and B are constants, depending on the probe materials and geometry, T is absolute temperature, and dT/dt is the rate of change of temperature with time.

Of course higher order equations can be used, such as quadratics or cubics in T, and second and third derivatives of temperature may be applied.

The constant, A, is calculated by calibrating the probe, in non-corrosive conditions, at two stable temperatures, for example, T0 and T1. If the change in indicated resistance (as calculated by the basic ratiometric method, is delta-r, then

A = delta-r / (T1 – T0)

The constant, B is calculated by placing the probe in non corrosive conditions in a temperature bath with a constant thermal ramp.

If the change in indicated resistance (as calculated by the basic ratiometric method, is delta-r, then

B = delta-r / (dTb/dt)   Where dTb/dt is the thermal ramp rate of the calibration bath.

An alternative method of providing temperature compensation may be achieved by carefully modelling the probe and a typical surrounding fluid. This is achieved using finite element analysis, taking care to duplicate the physical dimensions, and material properties, particularly the specific heat capacity and thermal conductivity, of the materials. This model can then be used to calculate the thermal profile of the active and reference elements, and hence the necessary correction to the computed resistance. One or more temperature sensors are used to provide inputs to the model.

A further alternative method of providing temperature compensation may be achieved by applying "fuzzy logic" or "neural network" computational methods. In this case, the neural network (or fuzzy logic) receives one or more temperature inputs and the uncompensated ratiometric resistance value, and computes the most appropriate temperature correction to the resistance value. The neural network is "trained" by placing the probe in non-corrosive temperature baths, and applying a variety of temperature ramps and step changes. During this process, the neural network creates a set of rules that always outputs a correction factor equal and opposite to the error created by the temperature conditions. This then enables the neural network to correct the probe

for temperature errors under real operating conditions. Provided probes are made to repeatable dimensions, and of consistent materials, it is possible to "train" the neural network on one probe of a particular type, and apply the resulting rules to other probes of a similar type. For the highest level of temperature correction, it is always preferable to "train" the neural network on the exact probe that is going to be used. In some cases, the pressure of the process fluid can effect the ratiometric resistance. It is of course possible to sense this pressure, and apply this extra input to the neural network to include this variable in the training, and correction, process.

The present invention will now be illustrated by way of example, in which figure 1 shows an electrical resistance probe, with active corroding element 1, and reference element 2. This probe is connected to electronic instrumentation, via connections 3,4,5,6, and 7. Low voltage current source, 8, can be switched on and off by microprocessor 16. When low voltage current source 8 is on, current flows through connection 3, elements 1 and 2, through connection 7, and through reference resistor 9. Amplifiers 10, 11 and 12 amplify the differential voltage across active element 1, reference element 2 and reference resistor 9 respectively. High-resolution analogue to digital converters, 13, 14, and 15 digitise the output of amplifiers 10, 11 and 12 respectively. The microprocessor, 16, collects a set of readings from ADCs 13,14 and 15 with the current source, 8 on. Microprocessor, 16, then collects a set of readings from ADCs 13,14 and 15 with the current source off. The microprocessor can then subtract the "off" set of readings from the "on" set of readings, to eliminate offsets due to thermal emfs in the wiring and connections. The microprocessor averages many sets of readings to improve noise immunity.

The traditional ratiometric measurement of the resistance of the active element,1, divided by the resistance of the reference element, 2, is taken by dividing the off-set corrected, and averaged values from ADC 13 by ADC 14 ("ratio A") . Furthermore, the resistance ratio of the reference element, 2, to the reference resistor, 9 ("ratio B") , is taken in a similar way by dividing results from ADC 14, by ADC 15. This ratio provides the resistance of the reference element, which is related to its temperature. As temperature is a useful parameter, the microprocessor calculates temperature using a standard linear calibration equation
$T = mR + c$ (m and c are calibration constants, and R is the resistance ratio).

The microprocessor runs a neural network algorithm, that takes the two ratios, ratio A and ratio B, and computes a correction factor, that is subtracted from ratio A. This corrected ratio is then used to finally calculate the metal thickness of the active element 1.

The neural network in the microprocessor is initially taught by presenting many different temperature transients and slopes to the network in a non-corrosive environment.

CLAIMS

1 A method of corrosion monitoring of an active element involving the use of a an active element and a reference element similar in form to, and incorporated in a network with, the active element and involving the sensing of the absolute temperature, or a function thereof, of the reference element.

2 A method as claimed in Claim 1 wherein the sensing of the absolute temperature or a function thereof is undertaken by way of a resistive temperature device or a thermocouple.

3 A method as claimed in Claim 1 wherein the sensing of the absolute resistance of the reference element is by way of low voltage /current source whose operation is regulated by way of a microprocessor

4 A method as claimed in any preceding claim wherein a neural network system is used to receive, as input, one or more temperature inputs and a first uncompensated resistance value, and to provide for the computation of an optimised temperature correction to the first uncompensated resistance value.

5 A method as claimed in Claim 4 wherein the neural network is initially subjected to a variety of temperatures changes (involving ramp or step temperature changes or both) in order to establish a thermal profile for the active and/or the reference elements.

6 A method as claimed in Claim 1 or Claim 2 wherein the measured absolute

temperature or the function thereof is used to apply a secondary correction to a calculated active element resistance, as computed from a basic ratiometric measurement.

7 A method as hereinbefore described with reference to the accompanying drawings.

Application No: GB 9910430.9	**Examiner:** David Brunt
Claims searched: 1-7	**Date of search:** 21 November 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): G1N (NADW, NAFG, NAHB)

Int Cl (Ed.7): G01N (17/00, 17/04, 27/04)

Other: Online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2286844 A	(ROHRBACK) see p.3 ll.17-19, p.6 ll.26-28, p.8 ll.3-9	1,2,6
X	GB 2266379 A	(ROHRBACK) see p.7 ll.4-8, p.10 l.7-p.11 l.5, Fig.5	1,2,6
X	GB 2081904 A	(ROHRBACK) see p.3 ll.13-34 & 85-117, Fig.4	1,2,6
X	GB 2080537 A	(SHELL) see p.3 ll.5-7, Fig.1	1,2,6
X	US 4196057	(MAY) see col.4 ll.61-65	1,2

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
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